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EXPERIMENT NO. 4
METACENTRIC HEIGHT

INTRODUCTION:

The metacentric height is a measurement of the initial static stability of a floating body. It is calculated as the distance between the centre of gravity of a ship and its metacenter. A larger metacentric height implies greater initial stability against overturning. Metacentric height also has implication on the natural period of rolling of a hull, with very large metacentric heights being associated with shorter periods of roll which are uncomfortable for passengers. Hence, a sufficiently high but not excessively high metacentric height is considered ideal for passenger ships.

OBJECTIVE:

This activity aims to find the metacentric height of the body under various conditions of loading.

APPARATUS AND SUPPLIES

The unit shown in Fig. 1 consists of a pontoon (*1*) and a water tank as float vessel. The rectangular pontoon is fitted with a vertical sliding weight (*2*) which permits adjustment of the height of the center of gravity and a horizontal sliding weight (*3*) that generates a defined tilting moment. The sliding weights can be fixed in any position using knurled screws. The position (*4*, *5*) of the sliding weights and the draught (*6*) of the pontoon can be measured using the scales. A heel indicator (*7*) is also available for measuring the heel angle.

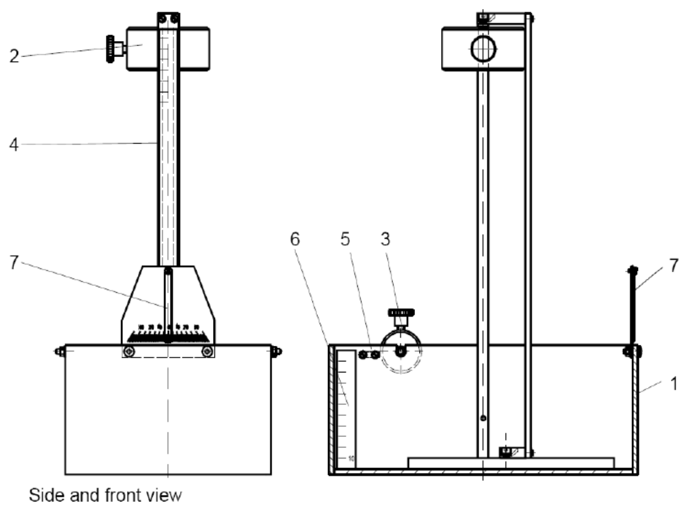


Figure 1- Different parts of experimental apparatus.

PROCEDURE

1. Set the horizontal sliding weight to position x from the center.
2. Move the vertical sliding weight to bottom position.
3. Fill the tank with water and insert the floating body.
4. Gradually raise the vertical sliding weight and read off angle on heel indicator. Read off height of sliding weight at top edge of weight and enter in table together with angle.
5. Raise the vertical sliding weight until the floating apparatus reach instability point and record this data point. Compare it with the previous results.

DISCUSSION:

Floating bodies are a special case; only a portion of the body is submerged with the remainder poking of the free surface. The buoyant force, F_A, which is the weight of the displaced water, *i.e*., submerged body portion, is equal to its dead weight, F_G. The center of gravity of the displaced water mass is referred to as the center of buoyancy, *A* and the center of gravity of the body is known as the center of mass, *S*.

In equilibrium position buoyant force, F_A, and dead weight, F_G, have the same line of action and are equal and opposite (see Fig. 2). A submerged body is stable if its center of mass locates below the center of buoyancy. However, this is not the essential condition for stability in floating bodies.

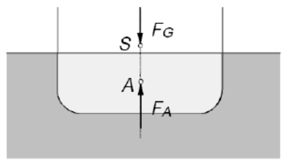


Figure 2- Buoyancy force and center of buoyancy.

A floating body is stable as far as a resetting moment exists in the event of deflection or tilting from the equilibrium position. As shown in Fig. 3, dead weight F_G and buoyant force F_A form a couple force with the lever arm of *b*, which provides a righting moment. The distance between the center of gravity and the point of intersection of line of action of buoyant force and symmetry axis, is a measure of stability. The point of intersection is referred to as the metacentre, *M*, and the distance between the center of gravity and the metacentre is called the metacentric height, z_m.

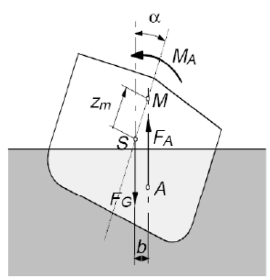


Figure 3- Metacentre and metacentric height.

The floating object is stable when the metacentric height z_m is positive, *i.e*., the metacentre is located above the center of gravity; else it is unstable. The position of the metacentre is not governed by the position of the center of gravity. It merely depends on the shape of the portion of the body under water. There are two methods of determining the metacentre position.

In the first method, the center of gravity is laterally shifted by a certain constant distance, x_s, using an additional weight, causing the body to tilt. Further vertical shifting of the center of gravity alters the heel angle, a. A stability gradient formed from the derivation dx_s/da is then defined which decreases as the vertical center of gravity position approaches the metacentre. If the center of gravity and metacentre coincide, the stability gradient is equal to zero and the system is stable. This problem is easily solved graphically (see Fig. 4). The vertical center of gravity position is plotted versus the stability gradient. A curve is drawn through the measured points and extrapolated as far as it contacts the vertical axis. The point of intersection with the vertical axis locates the position of the metacentre.

The metacentric height can also be evaluated theoretically using the following relationship:

$$\overline{MS} = \frac{I_o}{V_{sub}} - \overline{SA} \tag{1}$$

where *M*, *S*, and *A* are metacentre, center of gravity, and center of buoyancy, respectively. I_o is the area moment of inertia of the waterline footprint of the body about its tilt axis o and V_{sub} is the submerged volume of the body.

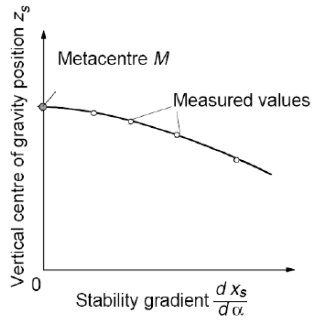


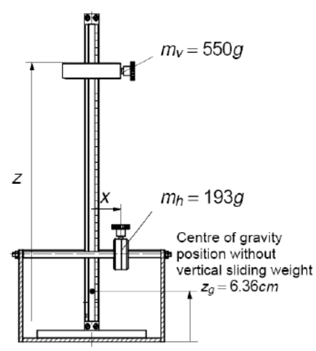
Figure 4- Graphical determination of metacentre

For the experimental setup of Fig. 5, the first step is to determine the position of the overall center of gravity x_s and z_s from the setting positions of the sliding weights. The horizontal position is referenced to the centreline:

$$x_s = \frac{m_h x}{m_h + m_v + m} = 0.055\, x \tag{2}$$

The vertical position is:

$$z_s = \frac{m_v z + (m + m_h) z_g}{m_h + m_v + m} = 5.364 + 0.156\, z \tag{3}$$



Total weight (not including sliding weights m_v and m_h), m=2770 g

Figure 5- Position and size of sliding weights

And the stability gradient is:

$$\frac{dx_s}{d\alpha} = \frac{x_s}{\alpha} \tag{4}$$

DATA AND RESULTS:

Table 4.1 – Graphical Determination of Metacentric Height

Trial	Vertical Distance z, (cm)	Horizontal Distance x, (cm)	Vertical Position of Center of Gravity z_s, (cm)	Horizontal Position of Center of Gravity x_s, (cm)	Angle of Heeling α, (°)	Slope Gradient $\frac{x_s}{\alpha}$
1						
2						
3						
4						
5						
6						

CLEANING PROCEDURE

1. After the experiment, remove the water from the tray.
2. Clean the apparatus and supplies and dry them thoroughly before returning them.

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Year and Section	
Group Number	
Group Members	

Date Started	
Date Finished	
Date Submitted	

4.1 DATA AND RESULTS:

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4.2 FORMULAS AND COMPUTATIONS:

4.3 DRAWINGS/SKETCHES/DIAGRAMS/GRAPHS:

4.4 SOURCES OF ERRORS:

4.5 REMARKS/CONCLUSION: